REMARKS

Attached hereto is a Petition and fee for a time extension of one month. No excess claims fee is due since excess claims have already been paid for.

Claims 28-58 are all of the claims pending in the present Application. Claims 1-27 are canceled, thereby rendering moot the Examiner's withdrawal from consideration of claims 1,2,4,5, and 14-27. New claims 52-58 are added to focus on a generic concept of the present invention.

It is noted that, notwithstanding any claim amendments made herein, Applicant's intent is to encompass equivalents of all claim elements, even if amended herein or later during prosecution.

Applicant gratefully acknowledges the Examiner's indication that claims 38 and 51 would be allowable if rewritten in independent format. Applicant has accordingly rewritten claim 38 but awaits to rewrite claim 51 until further considered by the Examiner, since the dependency of the previous version of claim 51 was confused.

I. THE CLAIMED INVENTION

As described and claimed, for example by claim 32, the present invention is directed to a semiconductor device including a plurality of copper (Cu) wiring lines and an insulating layer which insulates between the plurality of Cu wiring lines. The insulating layer has a surface region whose Cu concentration is equal to or higher than 10^{19} atoms/cm^3.

As mentioned in the previous Amendment, it is disclosed on page 11 at lines 11 to 20 and in Figure 4 that the Cu concentration of the surface region of the insulating layer is equal to 10^{19} atoms/cm^3. A minimal isolation between conductors is achieved by maintaining isolation between regions having concentration of 10^{19} atoms/cm^3.

By examining the relationship between the leakage current and the Cu concentration of the insulating layer, the inventor discovered that when the Cu concentration of the insulating layer reaches the order of 10^{19} atoms/cm^3, there is an influence of the leakage current. Therefore, by isolating conductors with at least this

amount of insulating layer, leakage current will not be significant and minimal separation between conductors can be reduced to approach this distance.

In the experiment that the inventor carried out, the Cu concentration in HSQ is in the order of 10^{19} atoms/cm^3 at a position which is 50 nm or less from the contact surface of the HSQ and the Cu wiring lines and is less than 10^{19} atoms/cm^3 at a position which is equal to or more than 50 nm (e.g., see Figure 4).

Therefore, the inventor found that if the thickness of HSQ is equal to or thicker than 50 nm, a device that is not influenced by the leakage current can be obtained. This result was found by the inventor carrying out an experiment, focusing on the relationship between the leakage current and the Cu concentration of the insulating layer. This result is not described or taught in the cited references.

The distribution of Cu concentration of the insulating layer differs by the conditions for forming the insulating layer and the conditions for manufacturing the device. Namely, the distribution of Cu concentration of the insulating layer is not unique to the insulating layer. Therefore, claims 28 to 37 are not apparent from the cited references.

II. THE PRIOR ART REJECTIONS

The Examiner alleges that claims 32-37 are rendered obvious by Lopatin or Avanzino, further in view of Applicant's Admitted Prior Art and that claims 39-50 are rendered obvious by Lopatin or Avanzino, further in view of Applicant's Admitted Prior Art, and further in view of Zhao. The Examiner further alleges that claims 28-31 are rendered obvious by Lopatin or Avanzino, further in view of Applicant's Admitted Prior Art, and further in view of Zhao or Subramanian.

Applicant respectfully disagrees.

A key feature of the present invention and an aspect that Applicant considers as a significant contribution to the art is the recognition of the concentration of diffused copper into the low-k layers. More specifically, Applicant's testing has demonstrated that HSQ has a threshold concentration of approximately 10^{19} atoms/cm^3 at which leakage becomes significant and that this concentration level occurs only within a predeterminable distance from the copper components, when using, for example, HSQ.

Therefore, by observing this predeterminable distance, the distance between copper components can be considerably minimized from the separations conventionally used in the art, while preserving leakage within acceptable limits. The prior art of record fails to recognize the significance of the diffused copper concentration in these isolation materials.

Thus, the prior art fails to recognize the significance of this parameter, much less recognize that copper separation can be considerably reduced in view of this copper diffusion concentration distance, without the need for a barrier material layer. In non-limiting exemplary embodiments, the present invention allows separation of copper lines in the neighborhood of 0.2 to 0.3 μm.

Hence, turning to the clear language of the claims, in none of Lopatin, Avanzino, Applicant's Admitted Prior Art, Zhao, or Subramanian is there any teaching or suggestion of:"... at least two of said wiring lines being separated from each other by approximately 0.2 to 0.3 μm", as required by independent claim 28.

Relative to independent claim 32, these references fail to teach or suggest: "... wherein said insulating layer has a surface region whose Cu concentration is equal to or higher than 10^{19} atoms/cm^3 around each said Cu wiring lines due to a diffusion of Cu from said Cu wiring lines and a separation distance between at least two of said Cu wiring lines approaches a minimum consistent with maintaining a separation between said surface regions."

Relative to new independent claim 52, there is no teaching or suggestion of: "A method of providing a minimal isolation thickness for a copper conductor in an integrated circuit, said method comprising: providing, for said copper conductor, a predetermined isolation thickness of a low permittivity insulating layer to comprise a high-concentration diffusion region of copper diffusing from said copper conductor, said predetermined isolation thickness based on a distance that copper diffuses from said copper conductor into said low permittivity insulating layer to a concentration of copper at which a leakage current becomes significant in said low permittivity insulating layer, said copper conductor and said low permittivity insulating layer having no barrier layer interposed therebetween, wherein said high-concentration diffusion region is located such as to be separated from any other similar high-concentration

diffusion regions and copper conductors, said predetermined isolation thickness thereby allowing a minimal isolation distance of said copper conductor in a circuit that approaches said predetermined isolation thickness."

Because of the recognition of the significance of this diffusion concentration and its subsequent utilization in minimizing conductor separation, Applicant submits that the present invention is clearly patentable over the prior art of record.

III. FORMAL MATTERS AND CONCLUSION

In view of the foregoing, Applicant submits that claims 28-58, all the claims presently pending in the application, are patentably distinct over the prior art of record and are in condition for allowance. The Examiner is respectfully requested to pass the above application to issue at the earliest possible time.

Should the Examiner find the application to be other than in condition for allowance, the Examiner is requested to contact the undersigned at the local telephone number listed below to discuss any other changes deemed necessary in a telephonic or personal interview.

The Commissioner is hereby authorized to charge any deficiency in fees or to credit any overpayment in fees to Attorney's Deposit Account No. 50-0481.

Respectfully Submitted,

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